

WHAT IS CLAIMED IS:

1. An apparatus for measuring characteristics of a sample, comprising:

a first source supplying a pump pulse of radiation to a first surface area of the sample to cause a disturbance of the sample at the first surface area;

a second source supplying a radiation probe pulse having a duration of less than about 1 picosecond for probing the sample at the first surface area, the probe pulse having a plurality of wavelength components in a bandwidth;

a converter converting the probe pulse into a corresponding converted pulse of longer duration than duration of the probe pulse prior to conversion so that each temporal portion of the converted pulse at a particular time corresponds to and comprises one of the wavelength components, and supplying the converted pulse to the sample at the first surface area;

a detector detecting substantially simultaneously changes in characteristics of the sample at the wavelength components of the temporal portions of the converted pulse after it has been modified by the sample and providing an output, wherein at least some of the temporal portions have been affected by the disturbance; and

a device analyzing the output of the detector or a signal derived therefrom to determine characteristics of the sample .

2. The apparatus of claim 1, wherein said disturbance causes a pulse to propagate in the sample, said converted pulse having a duration long enough for measuring propagation of the pulse in the sample.

3. The apparatus of claim 2, wherein said disturbance causes a pulse to propagate in the sample, said device analyzing changes in characteristics of the sample at different delay times of the portions relative to the arrival time of the pump pulse at the first surface area of the sample to determine characteristics of the sample.

4. The apparatus of claim 2, wherein said converted pulse has a duration not less than about 10 picoseconds.

5. The apparatus of claim 1, said detector detecting changes in characteristics of the sample at different delay times of the portions relative to the arrival time of the pump pulse at the first surface area of the sample by detecting changes in characteristics of the first surface area.

6. The apparatus of claim 5, said detector detecting changes in characteristics of the sample at different delay times of the portions relative to the arrival time of the pump pulse at the first surface area of the sample by detecting changes in optical characteristics of the first surface area.

7. The apparatus of claim 6, said detector detecting changes in characteristics of the sample at different delay times of the portions relative to the arrival time of the pump pulse at the first surface area of the sample by detecting changes in optical reflectivity of the first surface area.

8. The apparatus of claim 5, said detector detecting changes in characteristics of the sample at different delay times of the portions relative to the arrival time of the pump pulse at the first surface area of the sample by detecting changes in elevation of the first surface area.

9. The apparatus of claim 8, said detector comprising an interferometer detecting changes in elevation of the first surface area.

10. The apparatus of claim 1, said probe pulse having wavelength components across a substantially continuous spectrum in the bandwidth.

11. The apparatus of claim 1, said probe pulse having a duration of less than about 0.1 picosecond.

12. The apparatus of claim 1, said converter comprising a pulse stretcher.

13. The apparatus of claim 12, said pulse stretcher comprising a pair of gratings or an optical fiber.

14. The apparatus of claim 13, said pulse stretcher comprising the pair of gratings and an instrument capable of adjusting a distance between the pair of gratings, or an angle of incidence of the probe pulse to the pair of gratings.

15. The apparatus of claim 1, said detector comprising a spectrometer.

16. The apparatus of claim 15, said device analyzing output of the spectrometer to derive changes in characteristics of the sample at different delay times of the temporal portions of the converted pulse relative to the arrival time of the pump pulse at the first surface area of the sample.

17. The apparatus of claim 16, wherein said disturbance causes an elastic pulse to propagate in the sample, said device analyzing changes in characteristics of the sample at

different delay times of the portions relative to the arrival time of the pump pulse at the first surface area of the sample to determine characteristics of the sample.

18. The apparatus of claim 17, said sample having interfaces therein, wherein the elastic pulse propagates between the interfaces, causing echoes in the sample, said device analyzing changes in characteristics of the sample at different delay times of the temporal portions relative to the arrival time of the pump pulse at the first surface area of the sample to determine at least one distance between two interfaces of the sample.

19. The apparatus of claim 1, the second source providing a pair of a probe pulse and a reference pulse of radiation so that the probe pulse is directed to said first surface area when it is moved by the pump pulse and the reference pulse to a second surface area so that the pair is modified by the sample, said apparatus further comprising optics directing reflections of the pair of pulses from the sample to the detector so that the modified pair of pulses interfere at the detector to provide the output.

20. The apparatus of claim 19, wherein the probe pulse together with the modified probe pulse substantially share a common optical path with the reference pulse together with the modified reference pulse between the second source and the detector.

21. The apparatus of claim 1, further comprising a delay element that alters a timing relationship between the pump pulse and the converted probe pulse to calibrate the apparatus so that wavelength components detected by the detector and delay times of the temporal portions relative to the arrival time of the pump pulse at the first surface area of the sample are correlated.

22. The apparatus of claim 1, wherein said first source supplies radiation for the pump or probe pulse, and wherein the second source comprises optics that diverts a portion of the radiation supplied by the first source to supply the probe or pump pulse.

23. An apparatus for measuring disturbance of a sample, comprising:

a first source supplying a pump pulse of radiation to the sample to cause a disturbance of the sample;

a second source supplying a radiation probe pulse having a duration of less than about 1 picosecond for probing the sample, the probe pulse having a plurality of wavelength components in a bandwidth;

a converter converting the probe pulse into a corresponding converted pulse of longer duration than the probe pulse so that each temporal portion of the converted pulse at a particular time corresponds to and comprises one of the wavelength components, and supplying the converted pulse to the sample;

a detector detecting substantially simultaneously the wavelength components of the temporal portions of the converted pulse after it has been modified by the sample and providing an output, wherein at least some of the temporal portions have been affected by the disturbance; and

a device analyzing the output of the detector or a signal derived therefrom to determine said disturbance of the sample caused by the pump beam.

24. An apparatus for measuring characteristics of a sample, comprising:

a first source supplying a pump pulse of radiation to a first surface area of the sample to cause a disturbance of the sample at the first surface area;

a second source supplying to the sample a probe beam of radiation for probing the sample at the first surface area;

a detector detecting in a detection path radiation from the probe beam after it has been modified by the sample;

a converter in the detection path so that it passes to the detector radiation from the modified probe beam during time intervals in a temporal sequence of time intervals, where the

time intervals in the sequence correspond to displacement in a spatial record, wherein the radiation passed comprises radiation from the probe beam when it is affected by the disturbance; and

a device analyzing an output of the detector to determine said characteristics of the sample.

25. The apparatus of claim 24, wherein the converter converts into the spatial record the time intervals during which radiation from the probe beam is passed to the detector, and the device analyzes the detector output in accordance to the spatial record.

26. The apparatus of claim 24, wherein the converter comprises an optical gate having a gating mechanism that is controlled by the pump pulse.

27. The apparatus of claim 26, wherein the optical gate comprises a non-linear crystal.

28. The apparatus of claim 27, a gating pulse having a predetermined timing relationship with the pump pulse, said gating pulse propagating along a first direction in the crystal, causing a portion of the modified probe beam to be passed through a portion of the crystal along a second direction transverse to the first direction when the gating pulse reaches such portion of the crystal, wherein the detector comprises an array of detecting units arranged alongside the crystal, each detecting unit in the array detecting the modified probe beam after passing a portion of the crystal adjacent to such unit.

29. The apparatus of claim 28, wherein the array of detecting units arranged alongside the crystal in a third direction substantially parallel to the first direction, so that location of each

unit along the third direction corresponds to a time interval during which radiation from the probe beam is passed to the detector.

30. The apparatus of claim 29, wherein the device analyzes outputs of the detecting units in reference to their locations along the third direction.

31. The apparatus of claim 28, wherein the gating pulse alters locally a birefringence of the non-linear crystal.

32. The apparatus of claim 24, the second source supplying to the sample a substantially continuous wave probe beam of radiation.

33. The apparatus of claim 24, wherein the time intervals together extend over a time window, wherein the duration of the window is not less than about 20 picoseconds.

34. The apparatus of claim 24, the second source supplying to the sample a pulsed probe beam of radiation, with a pulse duration that is not less than about 20 picoseconds.

35. The apparatus of claim 24, further comprising a beam expander that expands radiation modified by the sample in a first direction before conversion by the converter into a beam elongated in the first direction.

36. The apparatus of claim 35, wherein the expanded beam comprises portions aligned in the first direction, said converter passing portions of the expanded beam in response to a gating pulse having a predetermined timing relationship with the pump pulse.

37. The apparatus of claim 36, wherein the detector comprises a detector array comprising detecting units aligned in a direction substantially parallel to the first direction, each unit detecting a portion of the modified probe beam after passing the converter.

38. The apparatus of claim 36, wherein the converter comprises a gating mechanism that passes portions of the expanded beam in response to arrival of the gating pulse.

39. The apparatus of claim 38, wherein the converter comprises a crystal and wherein the gating pulse propagates through the crystal along a direction substantially parallel to the first direction.

40. The apparatus of claim 39, wherein the gating pulse alters locally a birefringence of the crystal.

41. The apparatus of claim 24, wherein the time intervals precede and follow a time corresponding to arrival time of the pump pulse at the first surface area.

42. The apparatus of claim 24, wherein the time intervals together extend over a time window, and wherein duration of the window is not less than about 20 picoseconds.

43. The apparatus of claim 24, said detector detecting changes in characteristics of the sample at different times at which radiation from the probe beam is passed to the detector by detecting changes in characteristics of the first surface area.



44. The apparatus of claim 43, wherein the converter converts into a spatial record along a first direction the times at which radiation from the probe beam is passed to the detector, said detector comprising an array of detecting units arranged along a direction substantially parallel to the first direction.

45. The apparatus of claim 44, said detector detecting changes in optical characteristics of the first surface area caused by the pump pulse.

46. The apparatus of claim 45, said detector detecting changes in optical reflectivity of the first surface area.

47. The apparatus of claim 45, said detector detecting changes in elevation of the first surface area.

48. The apparatus of claim 47, said detector comprising an interferometer detecting changes in elevation of the first surface area.

49. The apparatus of claim 47, said interferometer interfering radiation from the probe beam modified by the sample with radiation from the probe beam that is not modified by the sample.

50. The apparatus of claim 24, said probe beam being substantially monochromatic.

51. The apparatus of claim 24, the second source providing a reference beam that is substantially coherent with the probe beam, wherein the modified probe beam and the reference beam interfere at the detector to provide the output.

52. An method for measuring characteristics of a sample, comprising:

supplying a pump pulse of radiation to a first surface area of the sample to cause a disturbance of the sample at the first surface area;

supplying a radiation probe pulse having a duration of less than about 1 picosecond for probing the sample at the first surface area, the probe pulse having a plurality of wavelength components in a bandwidth;

converting the probe pulse into a corresponding converted pulse of longer duration than duration of the probe pulse prior to conversion so that each temporal portion of the converted pulse at a particular time corresponds to and comprises one of the wavelength components, and supplying the converted pulse to the sample at the first surface area;

detecting substantially simultaneously changes in characteristics of the sample at the wavelength components of the temporal portions of the converted pulse after it has been modified by the sample and providing an output, wherein at least some of the temporal portions have been affected by the disturbance; and

analyzing the output or a signal derived therefrom to determine characteristics of the sample.

53. The method of claim 52, wherein said disturbance causes a pulse to propagate in the sample, said converted pulse having a duration long enough for measuring propagation of the pulse in the sample.

54. The method of claim 53, wherein said disturbance causes a pulse to propagate in the sample, wherein said analyzing analyzes changes in characteristics of the sample at different

delay times of the portions relative to the arrival time of the pump pulse at the first surface area of the sample to determine characteristics of the sample.

55. The method of claim 53, wherein said converted pulse has a duration not less than about 10 picoseconds.

56. The method of claim 52, wherein said detecting detects changes in characteristics of the sample at different delay times of the portions relative to the arrival time of the pump pulse at the first surface area of the sample by detecting changes in characteristics of the first surface area.

57. The method of claim 52, wherein said detecting detects changes in characteristics of the sample at different delay times of the portions relative to the arrival time of the pump pulse at the first surface area of the sample by detecting changes in optical characteristics of the first surface area.

58. The method of claim 57, wherein said detecting detects changes in characteristics of the sample at different delay times of the portions relative to the arrival time of the pump pulse at the first surface area of the sample by detecting changes in optical reflectivity of the first surface area.

59. The method of claim 56, wherein said detecting detects changes in characteristics of the sample at different delay times of the portions relative to the arrival time of the pump pulse at the first surface area of the sample by detecting changes in elevation of the first surface area.

60. The method of claim 52, said probe pulse having wavelength components across a substantially continuous spectrum in the bandwidth.

61. The method of claim 52, said probe pulse having a duration of less than about 0.1 picosecond.

62. The method of claim 52, said converting comprising stretching the probe pulse.

63. The method of claim 62, said pulse stretching comprising providing a pair of gratings or an optical fiber, and adjusting a distance between the pair of gratings, or an angle of incidence of the probe pulse to the pair of gratings.

64. The method of claim 52, said detecting comprising dividing radiation from the sample into its wavelength components.

65. The method of claim 64, wherein said analyzing analyzes the components to derive changes in characteristics of the sample at different delay times of the temporal portions of the converted pulse relative to the arrival time of the pump pulse at the first surface area of the sample.

66. The method of claim 65, wherein said disturbance causes an elastic pulse to propagate in the sample, wherein said analyzing analyzes changes in characteristics of the sample at different delay times of the portions relative to the arrival time of the pump pulse at the first surface area of the sample to determine characteristics of the sample.

67. The method of claim 66, said sample having interfaces therein, wherein the elastic pulse propagates between the interfaces, causing echoes in the sample, wherein said analyzing analyzes changes in characteristics of the sample at different delay times of the temporal portions relative to the arrival time of the pump pulse at the first surface area of the sample to determine at least one distance between two interfaces of the sample.

68. The method of claim 52, wherein a pair of a probe pulse and a reference pulse of radiation are provided so that the probe pulse is directed to said first surface area when it is moved by the pump pulse and the reference pulse to a second surface area so that the pair is modified by the sample, said method further comprising directing reflections of the pair of pulses from the sample to the detector so that the modified pair of pulses interfere at the detector to provide the output.

69. The method of claim 68, wherein the probe pulse together with the modified probe pulse substantially share a common optical path with the reference pulse together with the modified reference pulse.

70. The method of claim 52, further comprising altering a timing relationship between the pump pulse and the converted probe pulse to calibrate a system for carrying out the method so that wavelength components detected by the detector and delay times of the temporal portions relative to the arrival time of the pump pulse at the first surface area of the sample are correlated.

71. The method of claim 52, wherein said supplying comprises diverting a portion of the radiation supplied for the pump or probe pulse to supply the probe or pump pulse.

72. An method for measuring disturbance of a sample, comprising:

supplying a pump pulse of radiation to the sample to cause a disturbance of the sample;

supplying a radiation probe pulse having a duration of less than about 1 picosecond for probing the sample, the probe pulse having a plurality of wavelength components in a bandwidth;

converting the probe pulse into a corresponding converted pulse of longer duration than the probe pulse so that each temporal portion of the converted pulse at a particular time corresponds to and comprises one of the wavelength components, and supplying the converted pulse to the sample;

detecting substantially simultaneously the wavelength components of the temporal portions of the converted pulse after it has been modified by the sample and providing an output, wherein at least some of the temporal portions have been affected by the disturbance; and

analyzing the output of the detector or a signal derived therefrom to determine said disturbance of the sample caused by the pump beam.

73. An method for measuring characteristics of a sample, comprising:

supplying a pump pulse of radiation to a first surface area of the sample to cause a disturbance of the sample at the first surface area;

supplying to the sample a probe beam of radiation for probing the sample at the first surface area;

detecting by means of a detector in a detection path radiation from the probe beam after it has been modified by the sample;

passing to the detector radiation from the modified probe beam during time intervals in a temporal sequence of time intervals, where the time intervals in the sequence correspond to displacement in a spatial record, wherein the radiation passed comprises radiation from the probe beam when it is affected by the disturbance; and

analyzing an output of the detector to determine said characteristics of the sample.

74. The method of claim 73, wherein the passing comprises converting into the spatial record the time intervals during which radiation from the probe beam is passed, and the analyzing analyzes the detector output in accordance to the spatial record.

75. The method of claim 73, wherein the converting comprises a gating mechanism by means of a gating pulse having a fixed timing relationship with the pump pulse.

76. The method of claim 75, wherein the gating mechanism employs a non-linear crystal, and a gating pulse having a predetermined timing relationship with the pump pulse, said gating pulse propagating along a first direction in the crystal, causing a portion of the modified probe beam to be passed through a portion of the crystal along a second direction transverse to the first direction when the gating pulse reaches such portion of the crystal, wherein the detector comprises an array of detecting units arranged alongside the crystal, each detecting unit in the array detecting the modified probe beam after passing a portion of the crystal adjacent to such unit.

77. The method of claim 76, wherein the array of detecting units arranged alongside the crystal in a third direction substantially parallel to the first direction, so that location of each unit along the third direction corresponds to a time interval during which radiation from the probe beam is passed to the detector, wherein the analyzing analyzes outputs of the detecting units in reference to their locations along the third direction.

78. The method of claim 76, wherein the gating pulse alters locally a birefringence of the non-linear crystal.

79. The method of claim 73, wherein the time intervals together extend over a time window, wherein the duration of the window is not less than about 20 picoseconds.

80. The method of claim 73, wherein the probe beam of radiation comprises pulses with a pulse duration that is not less than about 20 picoseconds.

81. The method of claim 73, further comprising expanding radiation modified by the sample in a first direction before the conversion into a beam elongated in the first direction.

82. The method of claim 81, wherein the expanded beam comprises portions aligned in the first direction, wherein said converting passes portions of the expanded beam in response to a gating pulse having a predetermined timing relationship with the pump pulse.

83. The method of claim 82, wherein the detector comprises a detector array comprising detecting units aligned in a direction substantially parallel to the first direction, each unit detecting a portion of the modified probe beam after passing the converter.

84. The method of claim 82, wherein the converting comprises a gating mechanism that passes portions of the expanded beam in response to arrival of the gating pulse.

85. The method of claim 84, wherein the converting employs a crystal and wherein the gating pulse propagates through the crystal along a direction substantially parallel to the first direction.

86. The method of claim 85, wherein the gating pulse alters locally a birefringence of the crystal.



87. The method of claim 73, wherein the time intervals precede and follow a time corresponding to arrival time of the pump pulse at the first surface area.

88. The method of claim 73, wherein the time intervals together extend over a time window, and wherein duration of the window is not less than about 20 picoseconds.

89. The method of claim 73, said detector detecting changes in characteristics of the sample at different times at which radiation from the probe beam is passed to the detector by detecting changes in characteristics of the first surface area.

90. The method of claim 89, wherein the converting converts into a spatial record along a first direction the times at which radiation from the probe beam is passed to the detector, said detector comprising an array of detecting units arranged along a direction substantially parallel to the first direction.

91. The method of claim 90, wherein said detecting detects changes in optical characteristics of the first surface area caused by the pump pulse.

92. The method of claim 91, wherein said detecting detects changes in optical reflectivity or elevation of the first surface area.

93. The method of claim 91, said detecting comprising interfering radiation from the probe beam modified by the sample with radiation from the probe beam that is not modified by the sample.

94. The method of claim 73, said probe beam being substantially monochromatic.

95. The method of claim 73, further comprising providing a reference beam that is substantially coherent with the probe beam, wherein said detecting comprises interfering the modified probe beam and the reference beam at the detector to provide the output.